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Letter to the Editor

Jatropha curcas: A ten year story from hope to despair

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ABSTRACT

The story of *Jatropha curcas* (Jatropha) was started in 2003 when the Planning Commission of India decided 20% blending of Jatropha oil (biodiesel) in petroleum diesel by 2010 and 30% by the year 2030. After that China, Japan, Belgium, Brazil, Tanzania, Mexico, Thailand, Malaysia, Philippines, and East and South Africa have set their own plans to blend Jatropha oil in petroleum diesel. It is not unexpected that almost every paper about Jatropha starts its introduction with the energy, environment and economic benefits and wishful thinking of reducing global warming. Unfortunately, Jatropha could not succeed so far in energy sector as expected, for which it was the most popularized energy crop. Many of the actual investments and policy decisions on Jatropha have convincingly been made without any scientific and technological backup. It has become clear that the positive claims on Jatropha are numerous which have popularized it as a potential source in biodiesel production but many of them still remain as theoretical assumptions and have not been verified yet practically. This letter reports briefly the status of past hopes to ground reality on the basis of what a few scientific studies on Jatropha.

1. Introduction

The story of *Jatropha curcas* (Jatropha) was started in 2003 when the Planning Commission of India decided 20% blending of Jatropha oil in petroleum diesel for biodiesel by 2010 and 30% by the year 2030 [1–3]. Jatropha is a plant whose seed oil has the matching characteristics of diesel [4–6] therefore it is called biodiesel plant [7]. It was expected that Jatropha can grow and fruit on any type of wasteland without irrigation and agricultural inputs and the seeds of Jatropha contain 40–60% oil [6–9]. The peculiar features of this non-edible crop [10] like drought tolerance, pest resistance, rapid growth, easy propagation, higher oil content than other oil crops, small gestation period, adaptation to a wide range of environmental conditions, and the optimum plant size and architecture (which make the seed collection more convenient; actually inconvenient [11]) make this plant a special candidate for biodiesel industry [12]. Among the various sources of biodiesel production, Jatropha is favoured as a non-edible feedstock, though it ranks IV (Palm > *Calophylum inophyllum* > *Cocus* sp. > Jatropha) in assumed oil yield/ hectare [13,14]. Without any scientific agronomical study, several earlier reports, proceedings, expectations and assumptions anticipated seed yield of Jatropha ranging from 2 to 5 $\mathrm{Mg\,ha^{-1}}$ and even 7.8 to 12 $\mathrm{Mg\,ha^{-1}}$. We present a conceptual figure showing the failure of Jatropha policy (Fig. 1). As much as possible the feedstock should fulfill two main requirements: low production costs and large production scale. To consider any feedstock as a biodiesel source, oil yield per hectare is an important parameter [15].

The widespread attention on Jatropha can be estimated from '*Jatropha curcas*' keyword based search on science databases. We found 1441 and 1423 articles on 30th November, 2013 appearing since 2003, on Web of Science and Scopus, respectively. Surprisingly, this number (1441) is 94.6% of total articles (1523) published since 1987. Search within results for 'seed yield' keyword reduced number to 213 only. We analyzed results to rank the countries and found India was on top with 63 articles followed by China and Malaysia with 26 articles each. We further refined our initial search (1441 articles) with document types and found 85% (1225) documents are research articles (Fig. 2) in which India was on top with 404 articles. Jatropha opened the floodgate to the scientific community to grab funds and publish papers in high impact journals because seed oil of Jatropha has characteristics of biodiesel and this crop was non-native of arid, semiarid and subtropical regions. The objective of this letter is to present the current status of Jatropha seed yield per unit area. This letter has studied the existing scientific studies from the globe and verified the speculations.

2. Plantation scenario

By 2008, Jatropha was planted over an estimated 9×10^5 ha of land globally of which 85% was in Asia, 13% in Africa and the rest in Latin America, and by 2015 Jatropha is expected to be planted on 12.8 million ha worldwide [1]. Among the Asian countries, with more than 6×10^5 ha, India is the largest cultivator. In 2007, China claims to have 2 million hectares of Jatropha plantation and announced plans to plant an additional 11 million hectares across its southern states by 2010. Myanmar (Burma), Philippines as well as African countries have planted several million hectares [1,15]. In

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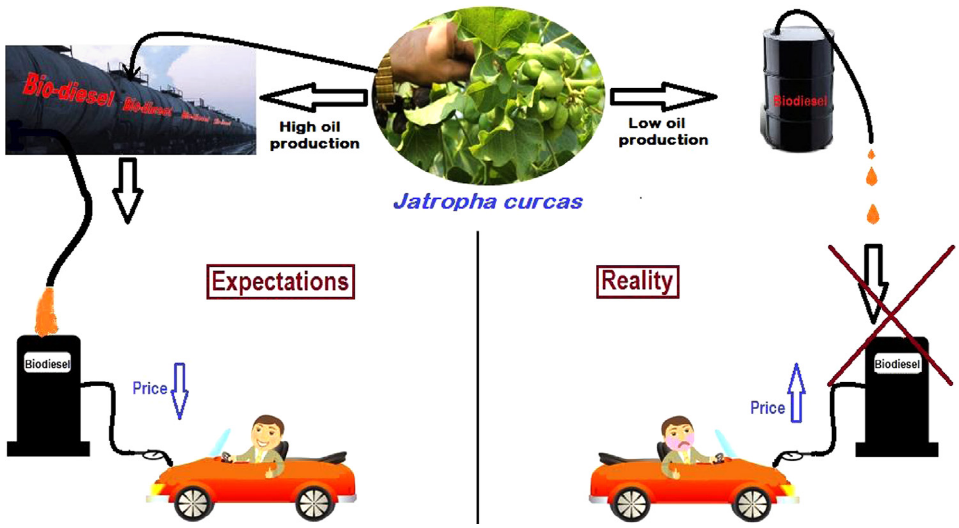

Fig. 1. Schematic presentation of hope from Jatropha and the actual condition. Expectations from Jatropha were high at global level to gain economic benefits but with this seed yield future Jatropha biodiesel policy is not bright.

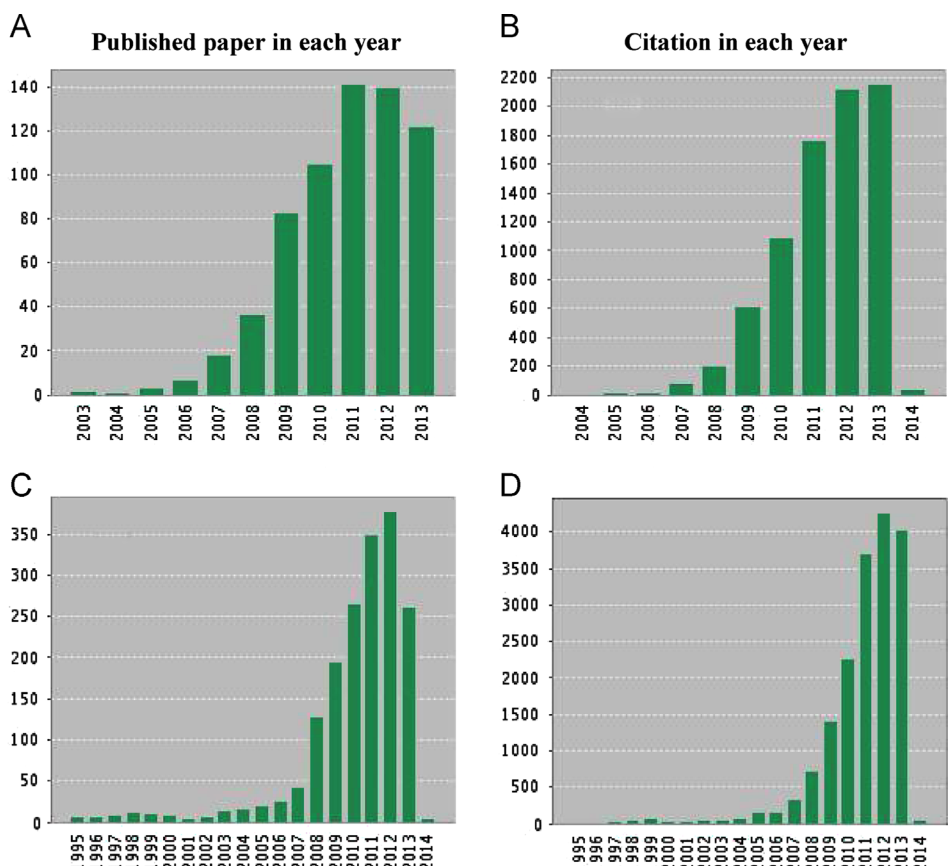

Fig. 2. *Jatropha curcas* keyword search results on Web of Science of Thomson Reuters. Trends, numbers [A and C] and citations [B and D] in each year since 2003 and 1995, of papers published on *J. curcas*.

India its widespread plantations since 2003 have not delivered any significant yield to accomplish even 5% blending in petroleum diesel. Now the 20% mandate has been shifted for 2017, which appears to be hardly achievable. In China the area of land suitable and moderately suitable for Jatropha plantation is 1.99×10^6 ha and 5.57×10^6 ha, respectively. It is estimated that if this total area (7.56×10^6) is put into use, the maximum net production potential of biodiesel from Jatropha would be 1.51×10^8 GJ/a [16]. There are several reviews on plantation scenario [46] and land availability for Jatropha in India [17–19], China [20], Malawi [21], Malaysia [9,22], Zimbabwe [23] and Sub-Sahara Africa [24]. Therefore it would be of little utility here to explain it in detail.

3. Actual agronomy

Experts from different countries agreed to ensure a seed yield of 4–5 Mg ha^{-1} yr^{-1} would be reasonable for its commercial viability. It was estimated that with average seed yield of 3.75 Mg ha^{-1}, oil content 30–35% and oil yield 1.2 Mg ha^{-1} Jatropha would be superior than the other oil seed crops like soybeans (USA) and rapeseed (Europe) which are producing 0.38 Mg and 1.0 Mg oil ha^{-1}, respectively [25]. Though breeding is the scientific tool to assess yield potentials of any crop, the problem is average seed yield potential, which is actually 0.5–1.4 Mg ha^{-1} yr^{-1} after five years of plant growth in a multi-location trial at different agro-climatic regions in India [11]. Twenty four elite accessions planted on sodic soil attained good plant architecture (height and branching pattern) but seed yield was again disappointing [26]. The average seed yield obtained at Belgium, after four years of cultivation, using the best known production techniques, was <0.5 Mg seed ha^{-1} [27]. In a recent assessment of global seed productivity of Jatropha, an average seed yield was compiled as 1.6 Mg ha^{-1} equivalent to 0.475 Mg ha^{-1} yr^{-1} biodiesel productivity, which could not be an economically feasible proposition for biodiesel production. The best seed yield was 0.35 Mg ha^{-1} in the Jatropha plots after 5 years of plant growth from South Africa [28]. A Jatropha silvi-pastoral production system in central-west Brazil in which hybrid seeds were used could not assure any significant seed yield, against the expectation of 2.4 kg $plant^{-1}$ [29]. Jatropha could not produce significant yield without fertilizers [30]. Seed yield increased from 0.1 Mg ha^{-1} to 0.5 Mg ha^{-1} with effect of nitrogen and potash @90 and 60 kg ha^{-1}. Similarly, the results are very unsatisfactory in Tanzania. After five year investment in Jatropha plantation the results were negative with a loss of US\$ 65 ha^{-1} on lands with yields of 2 Mg ha^{-1} of seeds and only slightly beneficial at US\$ 9 ha^{-1} with yields of 3 Mg when the average expected Jatropha seed yield on poor barren soils is only 1.7–2.2 Mg ha^{-1} [2]. Jatropha in Panzhihua has not changed local energy scenario and the industry has been threatened by many risks [31].

4. Disease incidence

Claims that Jatropha is free of pests and diseases are certainly not approved by recent studies. In these studies the plants were continuously threatened by severe viral infection (Cucumber mosaic virus), insects attack, rodents, powdery mildew, leaf spots, insect defoliations and fungal diseases in the soil [11,28]. The major pests affecting Jatropha in Belgium have been identified as leaf miner *Stomphastis thraustica*, the leaf and stem miner *Pempelia morosalis* and the shield-backed bug *Calidea panaethiopica* [32]. Fruit sap sucking predator *Scutellera perplexa* [33] and *Maconellicoccus hirsutus* have recently been investigated in India [34]. These pests cause about 60–80% damage to standing Jatropha crop at different study sites [11,28,32–34]. Despite its toxicity, Jatropha is not a pest and/ or disease resistant candidate.

5. Land reclamation

There are a few scientific confirmations that Jatropha sequester soil carbon, reclaim soil properties, enhance microbial diversity and does not show an elevated risk of invasion to adjacent land use systems [35–37]. Potential of Jatropha for soil carbon sequestration, restoration of fly ash landfills, phytoremediation of heavy metals and reclamation of sodic soils have been investigated through long term field experiments [38–40]. A study on the contribution of Jatropha to increase structural stability and carbon-nitrogen content in a degraded Indian entisol is also available in the literature [41]. Similarly, Wani et al. (2012) have assessed land rehabilitation through Jatropha by measuring soil organic carbon, microbial biomass and microbial counts in a range of semiarid degraded lands. In another study, Jatropha influenced the microbial community structure significantly in rhizosphere soils. In the rhizosphere soils of Jatropha, fungi were higher than bacteria and actinomycetes [42]. However, the environmental benefits like rehabilitation of barren land, soil reclamation and carbon sequestration in terms of carbon credit are not generally considered in benefit: cost ratio of agricultural economics for biodiesel production.

6. Conclusion and recommendations

Several merits of Jatropha have not been scientifically validated yet. Major knowledge gaps concerning basic ecological and agronomic properties (growth conditions, nutrient requirements, seed setting, oil content and the species genetics) make seed yield poorly predictable [8,14]. There are major technological challenges to ensure the economic biodiesel production from Jatropha. We do not have a suitable variety with standardized agro-technology to ensure a reasonable seed yield per unit area annually, which is an utmost requirement for the sustainable production. The genetic improvement for high yield and oil content at low agricultural inputs (water and nutrients) and tolerance to biotic and abiotic stresses are important traits to be manipulated through the molecular breeding and transgenic techniques [43]. We must strengthen its research for development and test it properly on all sorts of degraded lands across the different bio-geographic regions prior to recommending it for large scale cultivation at farmer's level. Countries having superior germplasm are reluctant to exchange their material for breeding researches and multi-location trials, and a narrow genetic base cannot succeed to develop a superior variety. Asymmetric flowering and poor fruiting are generally responsible for low productivity. Ratio of male to female flowers is quite high; pollinators, stigma receptivity, fertilization and development of embryo to a viable seed are main bottlenecks in good seed settings. Scientists are encouraged to work on reducing male: female flower ratio, on utilization of photosynthetic assimilation for reproductive parts and on traditional, conventional and molecular breeding for high yielding variety (HYV) [43].

A number of projects have been commenced for Jatropha research and a few of them have already been completed [9–12] but there is no significant achievement towards the yield improvement or enhanced oil recovery. A low productivity is inherent to many Jatropha germplasm and raising large-scale plantations using such untested planting material can lead to wasteful expenditures. When the availability of feedstock is insufficient to operate a plant continuously, their commercial exploitation would not be possible as an economic venture. Therefore, both the growers as well as entrepreneurs would be disappointed to follow onwards. After ten years experience, it was found that Jatropha can survive on wasteland but can't provide any significant yield with or without fertilizer inputs and irrigation until we don't have a HYV. Each country (mostly tropical and subtropical) has a vast variety of potential non-edible oil bearing plants. Most of them are naturally grown wild species which may or may not have yet been cultivated and harvested for oil production. Eleven tree species (*Azadirachta indica*, *Calophylluum ionophyllum*, *Garcinia indica*, *Hevea braziliensis*, *Madhuca indica*, *Mallotus Philippines*, *Mesua*

ferra, *Pongamia glabra*, *Ricinus communis*, *Salvadora* and *Shorea robusta*) have been identified in India for their importance in biodiesel industry and abundance in distribution [13]. There are some other species like *Camelina sativa, Gossypium hirsutum*, *Cynara cardunculus*, *Abutilon muticum, Simmondsia chinensis, Passiflora edulis*, *Carnegiea gigantean, Croton megalocarpus*, *Pachira glabra*, *Aleurites moluccana* and *Terminalia belerica* having high content of non-edible oil in their seeds [44]. These plants may also be explored for their suitability to meet the blending requirements rather than focusing on single candidate (Jatropha). Despite the unclear economical feasibility algal biodiesel is now in research. The results indicate that the environmental performance of algal biodiesel is comparable to that of Jatropha biodiesel. Both are potentially good candidates in reducing GHG in the range of 36–40% and 10–25% compared to fossil diesel [45].

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